4 myths about
Kees Schouhamer-Immink
IEEE medal of honor 2017

A life in circles

The red thread

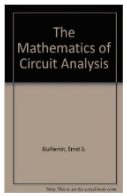
- What is a constrained sequence?

- The famous EFM code designed by Immink

8-Bit-Daten	14-Bit-Bitmuster (EFM)
00000000	01001000100000
00000001	10000100000000
00000010	10010000100000
00000011	10001000100000
00000100	01000100000000
00000101	00000100010000
00000110	00010000100000
00000111	00100100000000

Scientific (PhD) Genealogy of Kees Schouhamer Immink (coincidence? http://genealogy.math.ndsu.nodak.edu/)

Medal of honor: 1961



Ernst Guillemin (München, MIT)

The Mathematics of Circuit Analysis.

Robert Fano

John Wozencraft

Medal of honor: 2007

Thomas Kailath (Stanford)

exceptional development of powerful algorithms in the fields of communications, computing, control and signal processing

Piet Schalkwijk (TUE)

Medal of honor: 2017

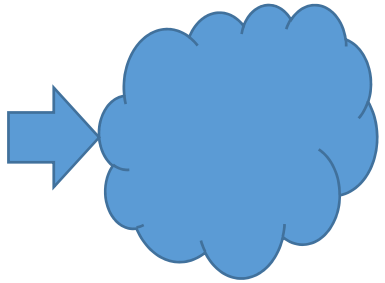
Kees Schouhamer Immink (TU Eindhoven)

For pioneering contributions to video, audio, and data recording technology, including compact disc, DVD, and Blue-ray

History: From mechanical to optical recording to … music-discs are already very old

Zink(Vinyl)-Schallplatte

CD/DvD



1885 Oscar Lochmann, Leipzig

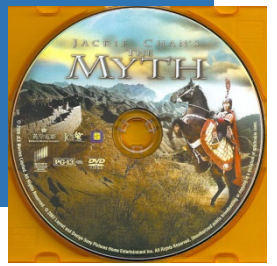
the first disc-playing musical box.

Emil Berliner mit der Urform seines Grammophons (1887)

digital optical recording, was invented in the late 1960s by James T. Russell.

Sony and Philips (CD) made it a commercial and technical success (1983)

4 myths about Kees Immink: #1
- Kees is the inventor of CD – He is not



Optical recording by James Russell

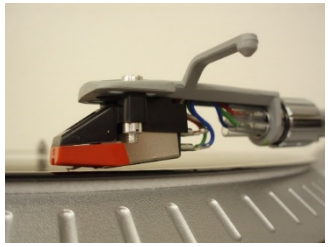
he succeeded in inventing the first *digital-to-optical recording and playback system*

The earliest patent by Russell, US3501586, was filed in 1966, and granted in 1970.

- Sony and Philips paid royalties from CD player sales to Battelle and to ORC
- Time-Warner and other disc manufacturors payed $30 million for patent infringement in 1996
- *the patents properly belonged to Russell's employer, he never got a cent out*

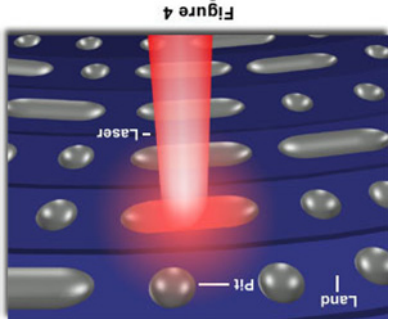
Anonymus group leader at Philips Research : we did not know about Russell‘s patents??

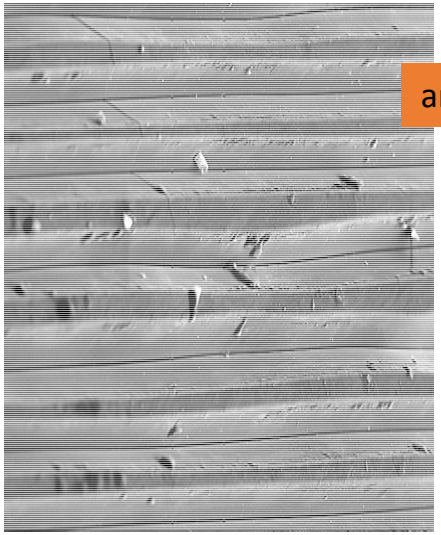
There are **principle differences** between a vinyl record and a CD



Needle with direct contact

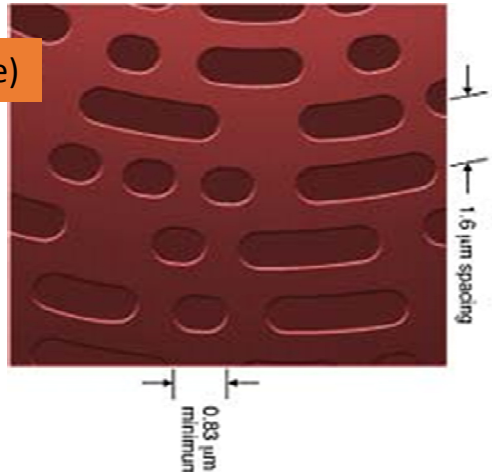
laser





analog (continuous)

digital (discrete)

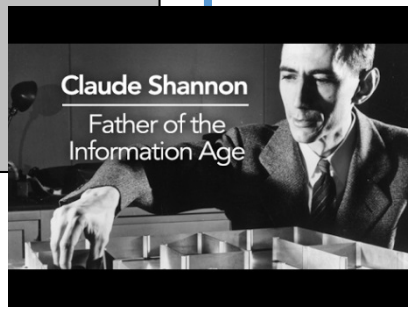


Why digital (binary) instead of analog?

Easier to implement:

- error correction
- data reduction
- encryption
- synchronization
- formatting
- …

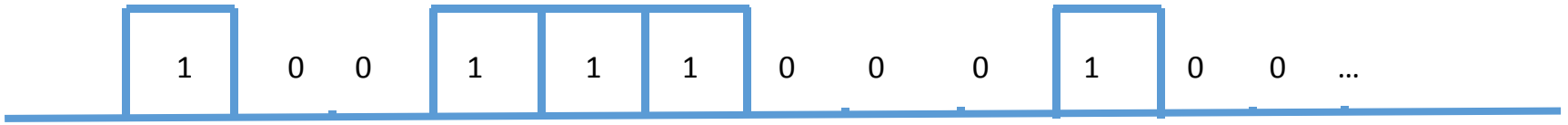
Higher Quality at lower Cost



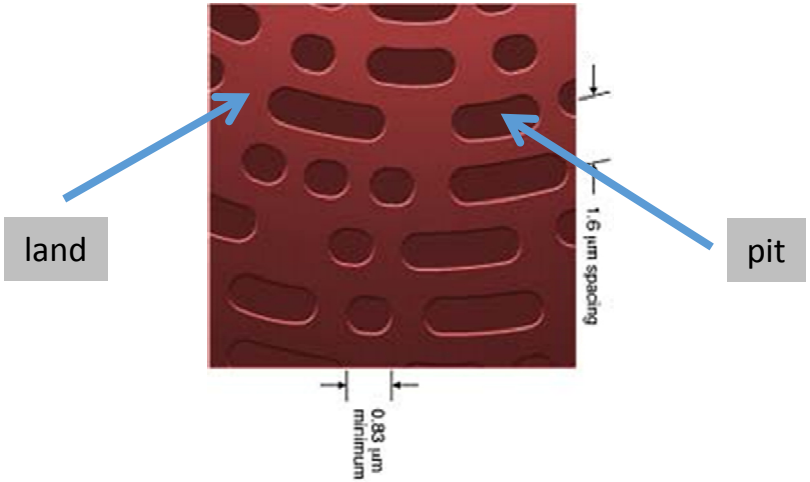
Medal of honor 1966

What is the **writing** principle on CD ?

- Music is represented by a sequence of bits (0 and 1)

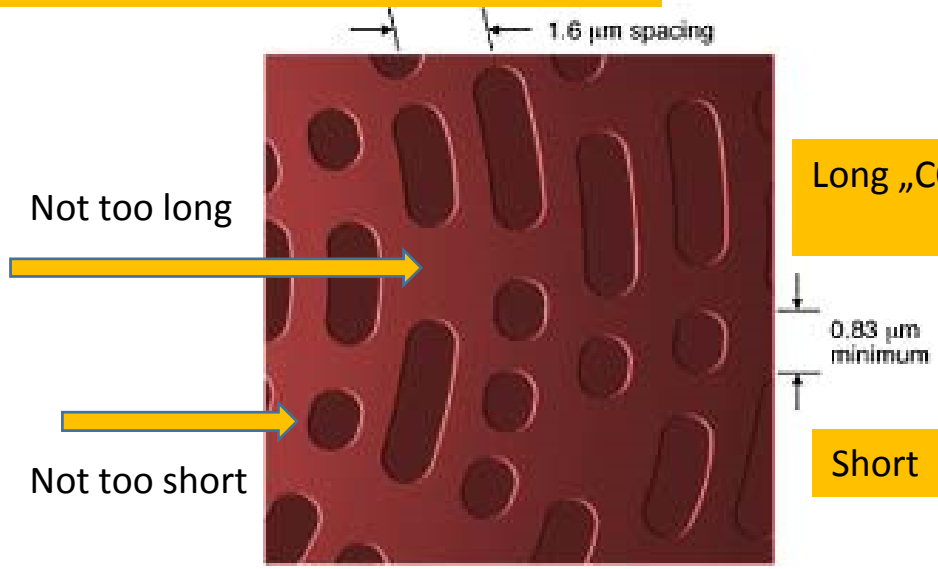


- Groups of 8 bits are converted into symbols suited for the medium CD (modulation)



What are the symbol constraints for writing on a CD ?

Symbol length has discrete values!



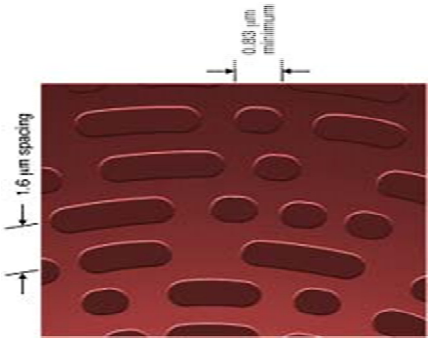
Long „CONSTANT“ sequences give synchronization problems
„we lose track“

Short symbol duration gives detection problems

Words are written as CD landscapes!
For CD: Pits and lands have minimum length 3

Information is in the transition!

0 0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0



Minimum run length: d- constraint for **good detection**

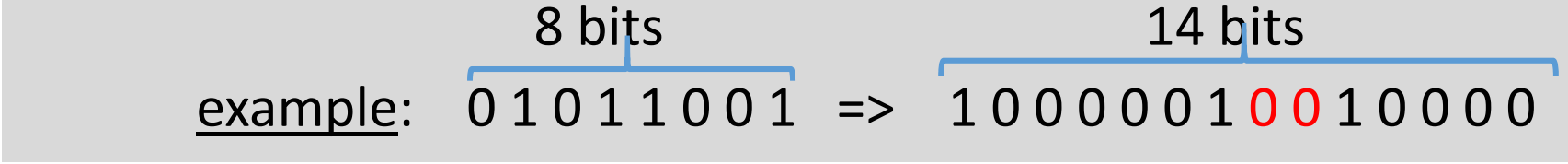
d = 2 gives length 3 in the landscape

there are **277** words of length 14 with at least **two** 0's between two 1's

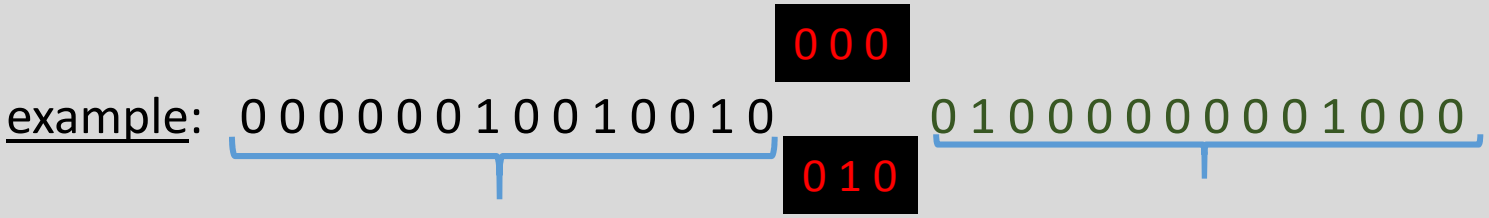
(for 8 bits we need only 256 words)

Immink modulates 8 bits (music) into constrained words of length 14

- constraints : at least two 0‘s between two 1‘s

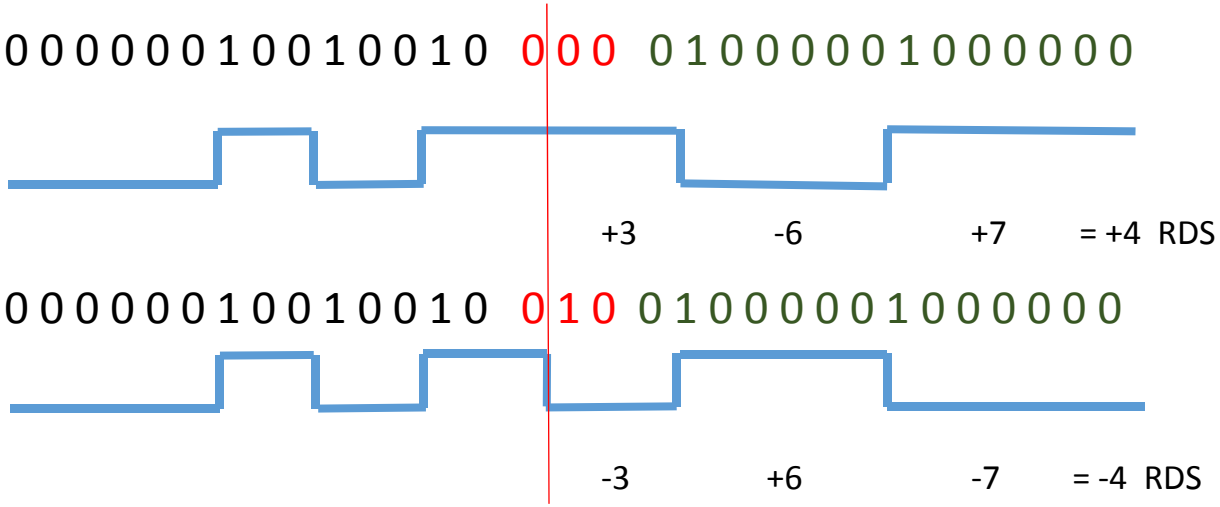


- words are stored using 3 merging bits (to satisfy the constraint we need only 2!)



what was Immink‘s idea?

Words are written as CD landscapes!

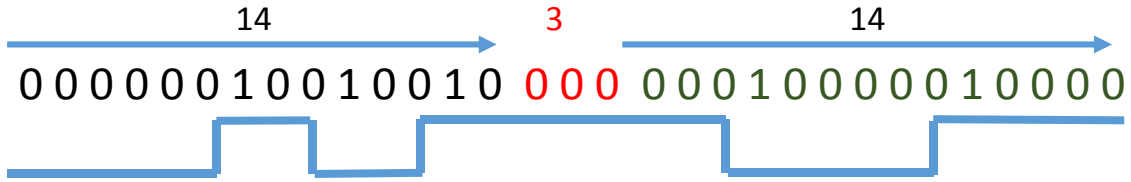


WE HAVE SOMETHING TO CHOSE!

This is what engineers like to do!

Fact: the **low frequency spectral properties can be improved** (Running Digital Sum) !

Core idea for the famous EFM (2,10) modulation code for CD (patent)



CONSTRUCTION: there are **277** words of length 14 with at least 2 0's between 2 1's

- remove all words with a segment of 11 or more 0's
- remove all words with 9 or 10 zeros at the beginning or end

Then,

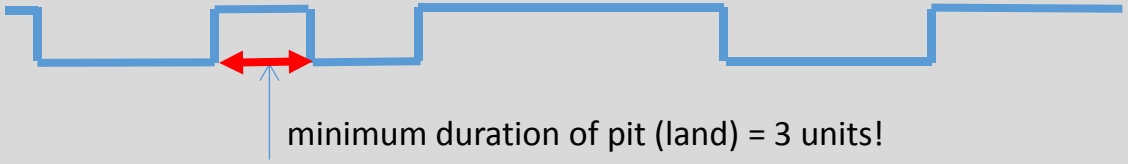
*277 – 20 = 257 words left, JUST enough to store 8 bits ≡ **256 words***

Result 1: the combination of words has a **maximum of k = 10 (ten)** 0's between 2 1's *for landscape **variation***

Result 2: the **minimum** number of zeros is 2!

Actually, there is one more important property (not many people talk about)

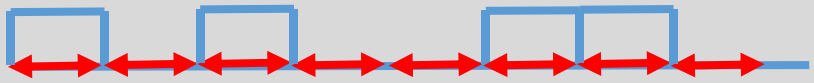
Constrained code: 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0



8 information bits
in 17(16) positions

minimum duration of pit (land) = 3 units!

Traditional coding: pits and lands must have the same mimimum duration

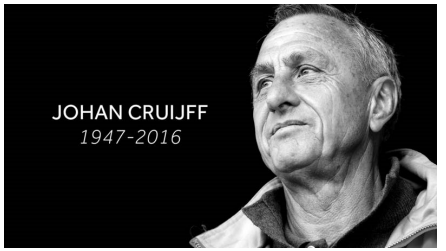


8 information
bits
in 24 positions

minimum duration of pit (land) = 3 units

DENSITY GAIN ≈ 30%

A disadvantage can have advantages (Johan Cruijff)



Sony and Philips cooperated (?)

Toshi Doi and ?

SONY(Toshi Doi, Ed. Rh.-1981):

Kees, we take your code if you can implement it with less than 100 gates!

On an Apple !! Immink succeeded to beat Sony!

This is the CD patent for the EFM code

United States Patent [19]

Immink et al.

[11] **Patent Number: 4,501,000**

[45] **Date of Patent: Feb. 19, 1985**

[54] **METHOD OF CODING BINARY DATA**

[75] Inventors: **Kornelis A. Immink; Jakob G. Nijboer,** both of Eindhoven, Netherlands; **Hiroshi Ogawa; Kentaro Odaka,** both of Tokyo, Japan

4

[73] Assignee: **Sony Corporation,** Tokyo, Japan

[21] Appl. No.: **286,982**

[22] Filed: **Jul. 27, 1981**

[51] **Int. Cl.** **H03K 13/02**

[52] **U.S. Cl.** ..... **375/25;** 375/106; 340/347 DD

[58] **Field of Search** ..... 375/18, 19, 25, 106, 375/112; 340/347 DD; 360/40, 48; 371/55, 57; 358/13

[56] **References Cited**

Assistant Examiner—Stephen Chin
Attorney, Agent, or Firm—Lewis H. Eslinger; Alvin Sinderbrand

[57] **ABSTRACT**

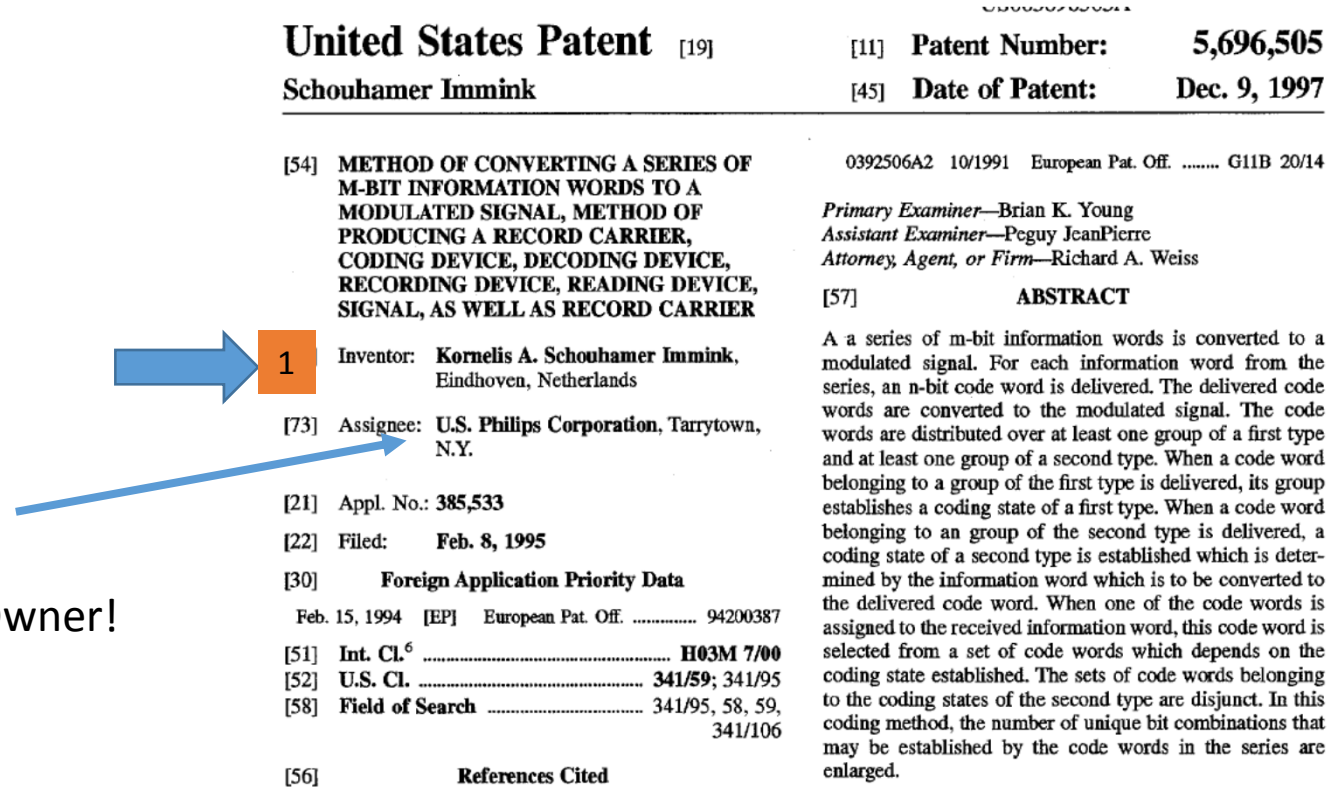
A system for block encoding words of a digital signal achieves a maximum of error compaction and ensures reliability of a self-clocking decoder, while minimizing any DC in the encoded signal. Data words of m bits are translated into information blocks of n_1 bits ($n_1 > m$) that satisfy a (d,k)-constraint in which at least d "0" bits, but no more than k "0" bits occur between successive "1" bits. The information blocks are catenated by inserting separation blocks of n_2 bits therebetween, selected so that the (d,k)-constraint is satisfied over the boundary between any two information words. For each information word, the separation block that will yield the lowest net digital sum value is selected. Then, the encoded

owner is Sony!?

Takanawa Prince Hotel (Shinagawa), close to Sony headquarters

+

The patent for the DvD, EFM+ , has only one inventor



United States Patent [19]

Schouhamer Immink

[11] **Patent Number: 5,696,505**

[45] **Date of Patent: Dec. 9, 1997**

[54] **METHOD OF CONVERTING A SERIES OF M-BIT INFORMATION WORDS TO A MODULATED SIGNAL, METHOD OF PRODUCING A RECORD CARRIER, CODING DEVICE, DECODING DEVICE, RECORDING DEVICE, READING DEVICE, SIGNAL, AS WELL AS RECORD CARRIER**

1

[75] Inventor: **Kornelis A. Schouhamer Immink**, Eindhoven, Netherlands

[73] Assignee: **U.S. Philips Corporation**, Tarrytown, N.Y.

[21] Appl. No.: **385,533**

[22] Filed: **Feb. 8, 1995**

[30] **Foreign Application Priority Data**

Feb. 15, 1994 [EP] European Pat. Off. 94200387

[51] **Int. Cl.**[6] **H03M 7/00**

[52] **U.S. Cl.** **341/59**; 341/95

[58] **Field of Search** 341/95, 58, 59, 341/106

[56] **References Cited**

0392506A2 10/1991 European Pat. Off. G11B 20/14

Primary Examiner—Brian K. Young
Assistant Examiner—Peguy JeanPierre
Attorney, Agent, or Firm—Richard A. Weiss

[57] **ABSTRACT**

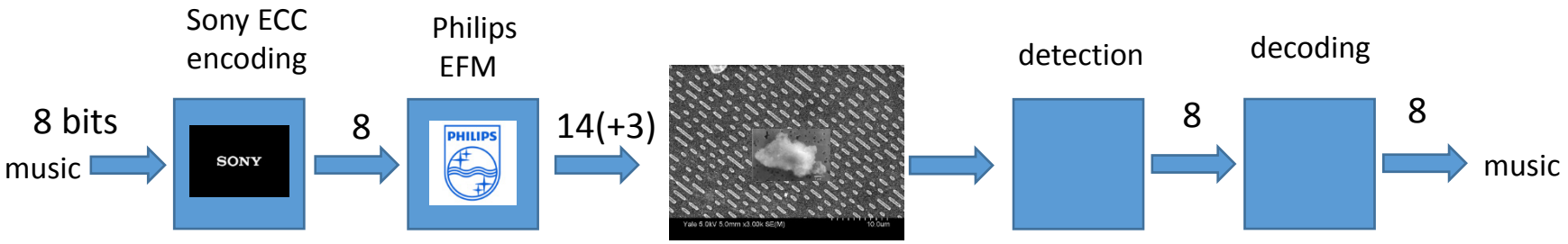
A a series of m-bit information words is converted to a modulated signal. For each information word from the series, an n-bit code word is delivered. The delivered code words are converted to the modulated signal. The code words are distributed over at least one group of a first type and at least one group of a second type. When a code word belonging to a group of the first type is delivered, its group establishes a coding state of a first type. When a code word belonging to an group of the second type is delivered, a coding state of a second type is established which is determined by the information word which is to be converted to the delivered code word. When one of the code words is assigned to the received information word, this code word is selected from a set of code words which depends on the coding state established. The sets of code words belonging to the coding states of the second type are disjunct. In this coding method, the number of unique bit combinations that may be established by the code words in the series are enlarged.

Owner!

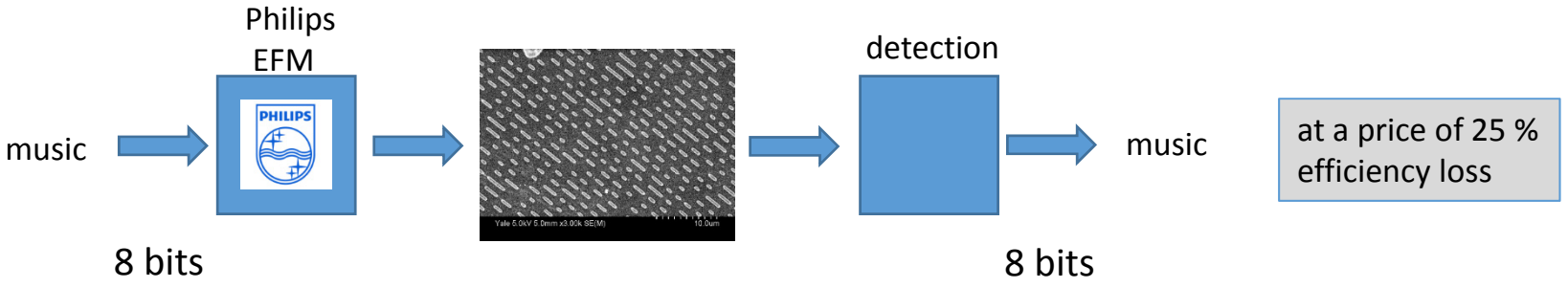
Suppose that you are in a hurry at the airport and they ask you to spell your name (K S-I)!

The CD is very noisy (dust, scratches, etc)

SONY contributed error correcting (Reed-Solomon) codes!

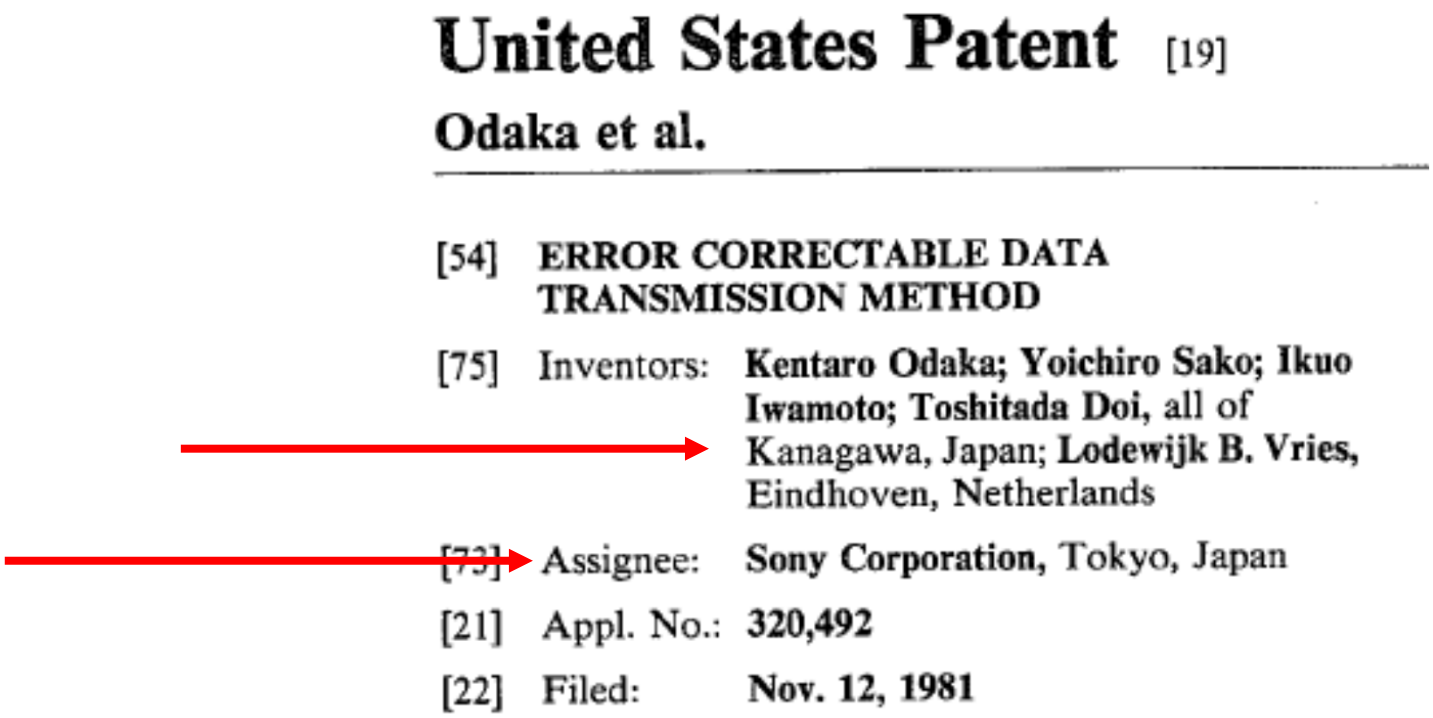


As a result: this situation is „equivalent“ to



at a price of 25 % efficiency loss

Contribution to Error control of CD!



United States Patent [19]

Odaka et al.

[54] **ERROR CORRECTABLE DATA TRANSMISSION METHOD**

[75] Inventors: **Kentaro Odaka; Yoichiro Sako; Ikuo Iwamoto; Toshitada Doi,** all of Kanagawa, Japan; **Lodewijk B. Vries,** Eindhoven, Netherlands

[73] Assignee: **Sony Corporation,** Tokyo, Japan

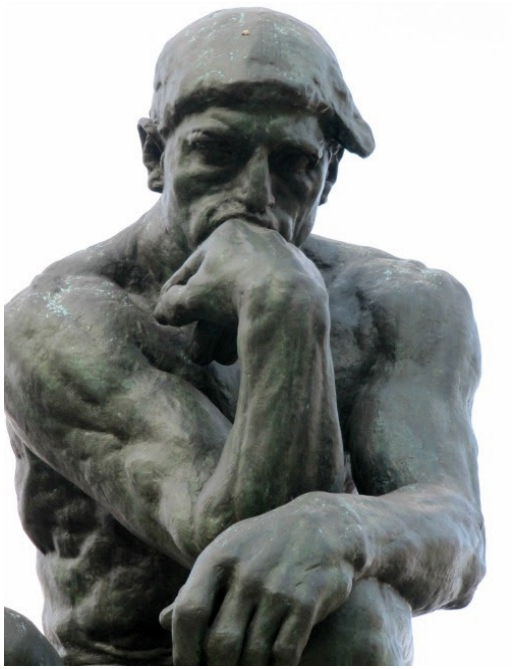
[21] Appl. No.: **320,492**

[22] Filed: **Nov. 12, 1981**

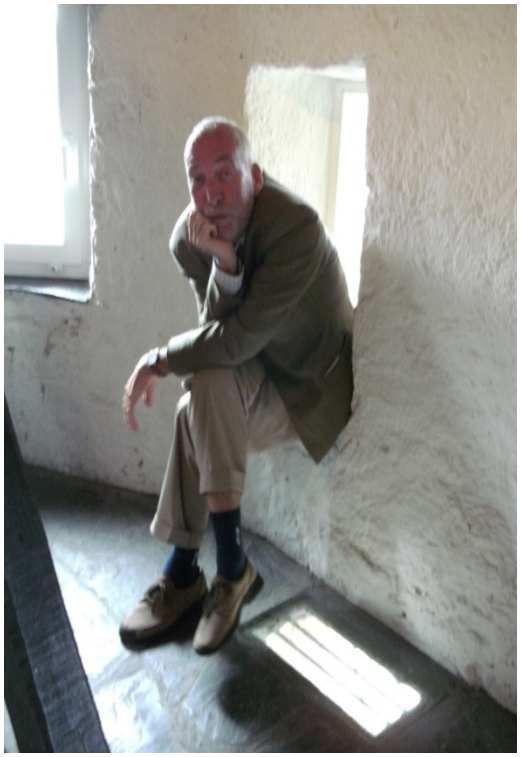
Also owned by Sony!?

CIRC

concatenated codes:
David Forney, Grand-uncle (brother of opa Tom Kailath)

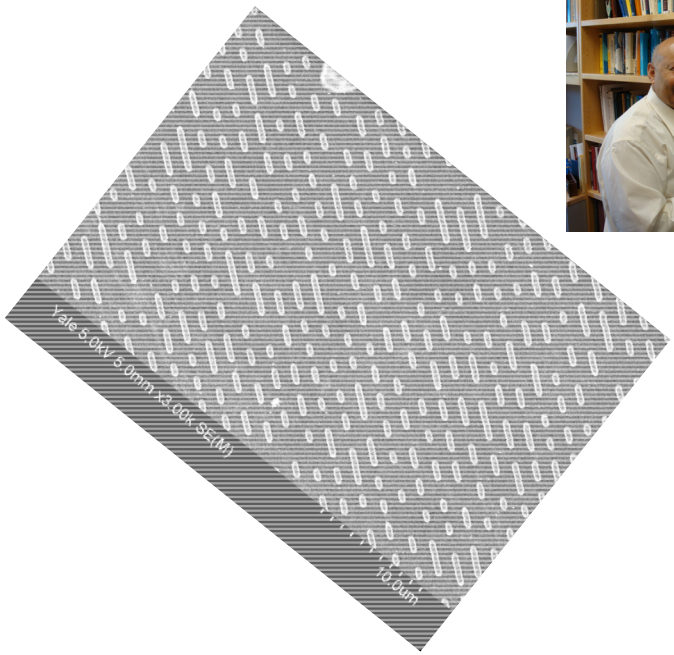


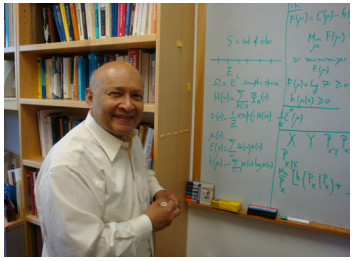
IEEE medal of honor
2015



We also need to follow the correct tracks (control)!

T.Kailath, Control
Scientific Grandfather





This requires a sequence with regular changes: here is the k-constraint!

The third essential patent in CD

United States Patent [19]

Kramer and Bouwhuis in 1991!

Piet Kramer:

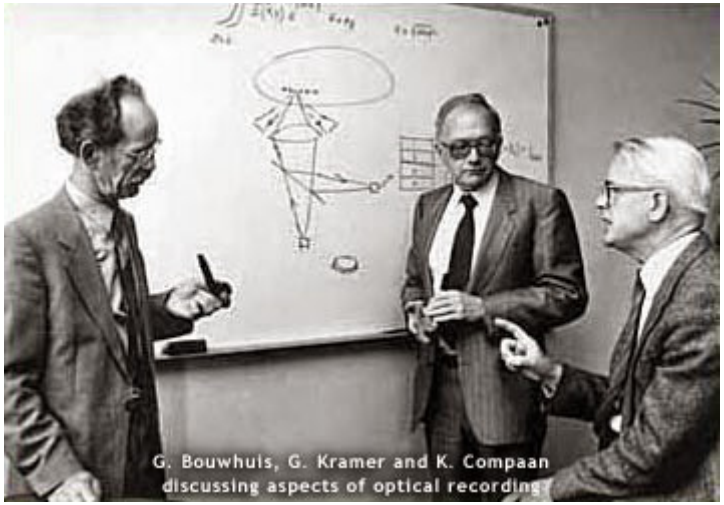
[54] **REFLECTIVE, OPTICAL RECORD CARRIER**

[75] Inventor: **Pieter Kramer**, Eindhoven, Netherlands

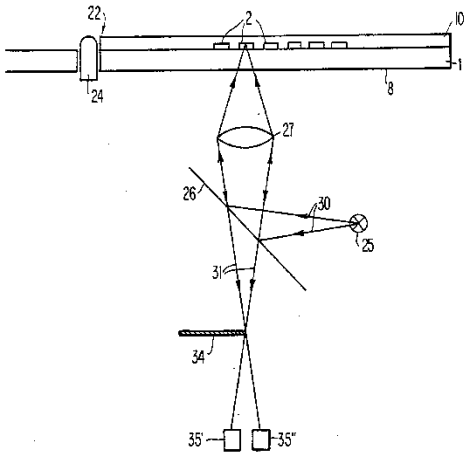
[73] Assignee: **U.S. Philips Corporation**, New York, N.Y.

[21] Appl. No.: **858,550**

[22] Filed: **Apr. 23, 1988**



U.S. Patent Nov. 26, 1991 Sheet 3 of 3 5,068,846

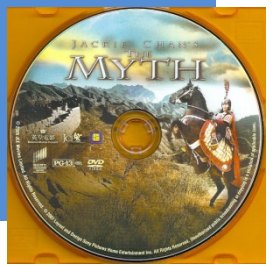


Patent No. 5,068,846
Patented: November 26, 1991

On petition requesting issuance of a certificate for correction of inventorship pursuant to 35 U.S.C. 256, it has been found that the above identified patent, through error and without deceptive intent, improperly sets forth the inventorship. Accordingly, it is hereby certified that the correct inventorship of this patent is:

Pieter Kramer,
Gijsbertus Bouwhuis

4 myths about Kees Immink: #2



- Kees was a professor in South Africa

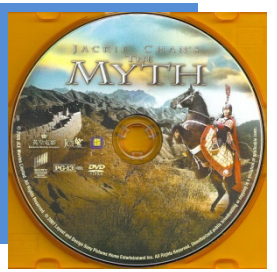
- no!
- but …

Capetown, 1993

Dr h.c. at UJ

teaching with a German colleague

4 myths about Kees Immink: #3



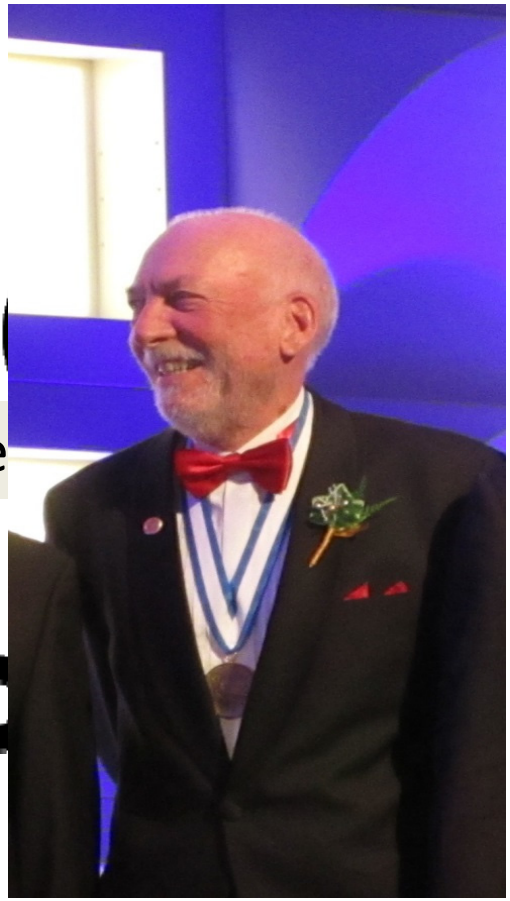
- Kees became rich of his work on CD at Philips
- no!

Suppose she/he gets only 0.001 Euro per CD.
Is that too much? (Philips got 10cts)

How many CDs are sold?

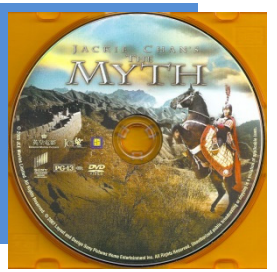
By 2007, 200 billion CDs have been sold worldwide

Unfortunately, the dutch patent law is not friedly for inventors, But …



if the invention is made by an employee of a university or research institution, the employer is entitled to the patent, (*Art. 12 (1) Rijksoctrooiwet 1995*).

4 myths about Kees Immink: #4



- Immink likes the army and authority
- Incorrect!

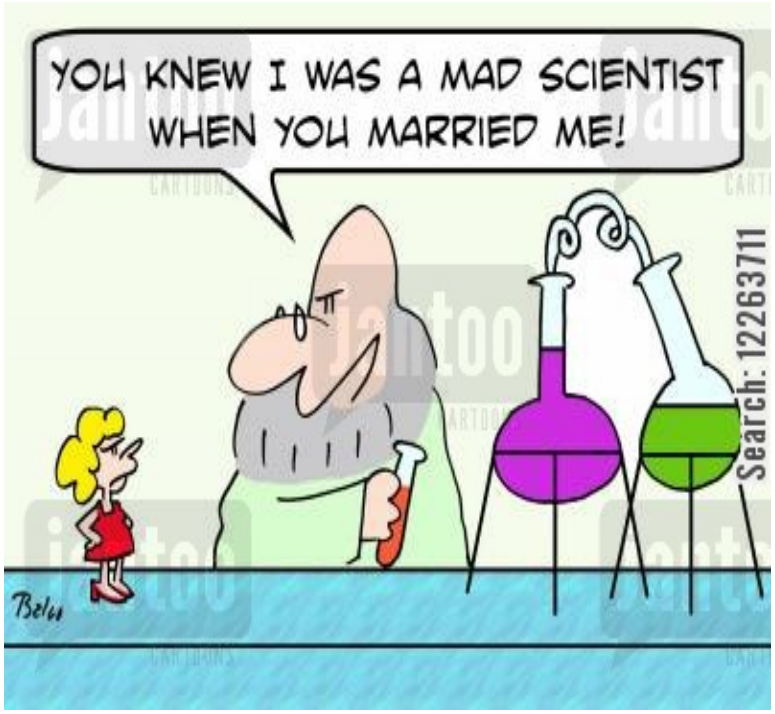
Samurai Kees Japan 2015

Knight in the Order of Oranje-Nassau (2000)

Trying to enter the **„foreign legion“**

BUT:
- Left the Army with S5! Comment Philips: one fool more or less at Research doesn't matter`
- Kees: *at Philips Research(then), you were your own boss, lots of freedom*
- left Philips at age 51*: not enough scientific freedom necessary to function and being creative*

What to do after retirement at Philips ?



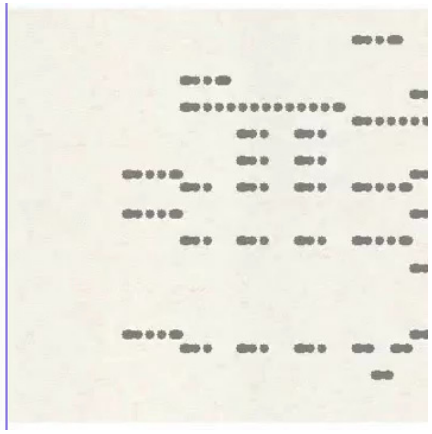
Use IEEE medal of honor:

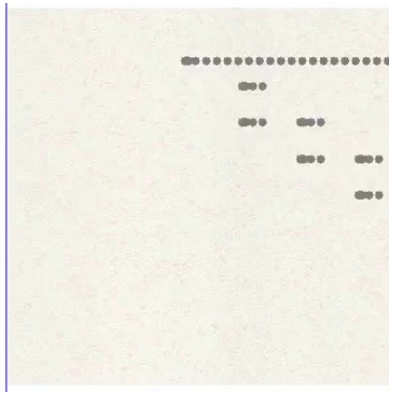
CONGRATULATIONS to BOTH of YOU!

My favorite digital recording machine

Constrained writing (programming)!

Time for a demonstration!





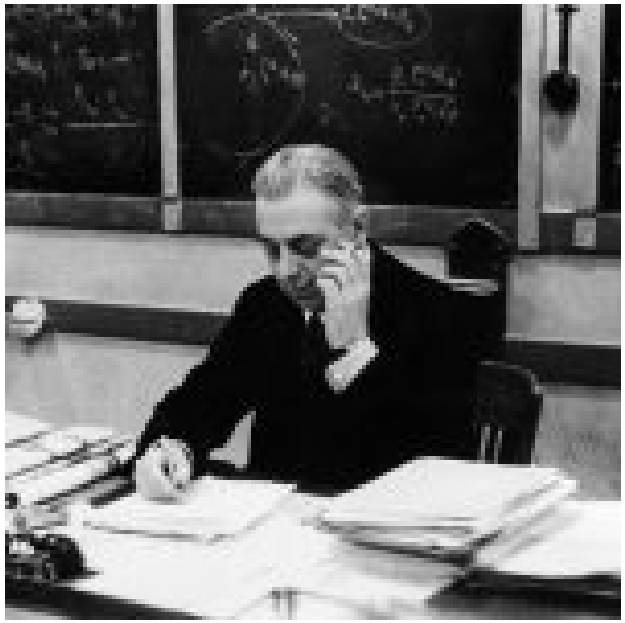
http://www.youtube.com/watch?v=wF69g0-uh08
http://www.youtube.com/watch?v=jRo8AZzTjRg

A proud „grand-father“

Piet Schalkwijk, TUE

Balthasar Van der Pol (Philips Research) IEEE medal of Honor (1935)

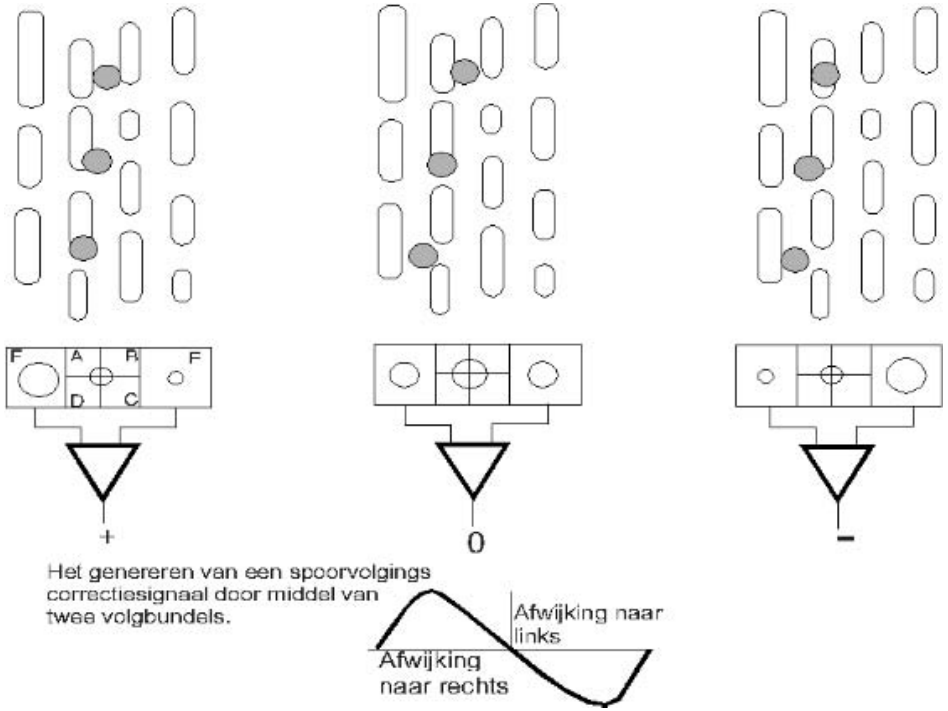
- "For his fundamental studies and contributions in the field of circuit theory and electromagnetic wave propagation phenomena.

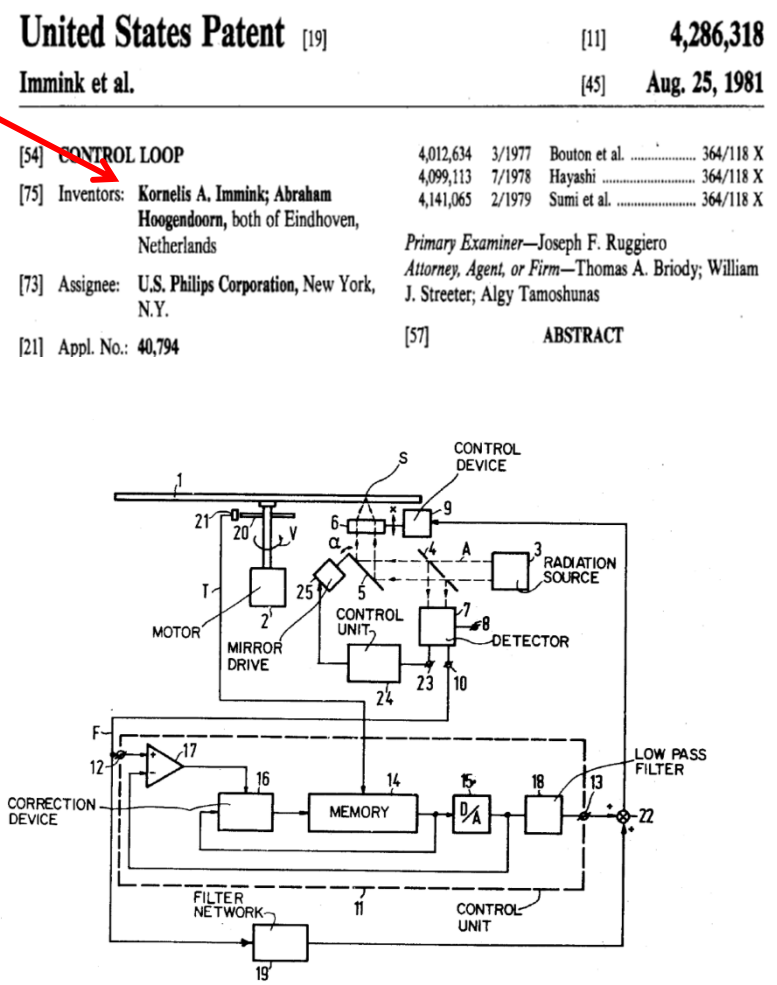


Het NatLab leek sterk op het AT&T Bell Laboratorium in de Verenigde Staten. Er werd behalve industrieel ook fundamenteel onderzoek gedaan.

Van der Pol heeft belangrijke bijdragen geleverd aan onderzoek naar de voortplanting van radiogolven,

Sporen volgen – follow tracks

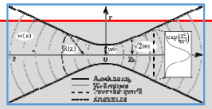




T.Kailath, Control

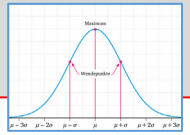
Even C.F. GAUSS contributed to the CD principles

- die gaußsche Optik, a mathematical description of laser light propagation



- the first **binary** wired communication link: 1833, Gauss, Wilhelm Weber and Carl August von Steinheil (München)

- description of Gaussian noise

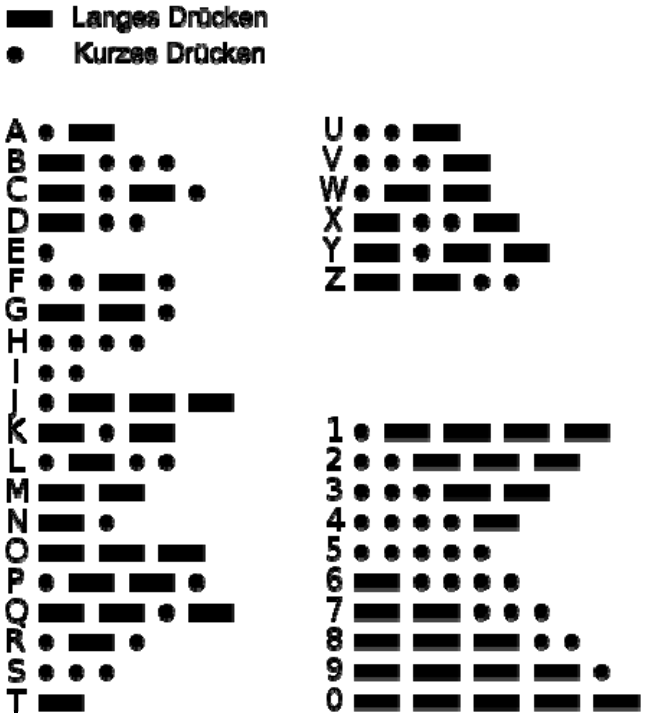


Gauss and Weber (1833)

r	a	rrr	c,k	lrl	m	lrrr	w	llrr 4
l	e	rrl	d	rll	n	rrll	z	lllr 5
rr	i	rlr	v,y	rrrr	p	rlrl	0	llrl 6
rl	o	lrr	g	rrrl	r	rllr	1	lrll 7
lr	u	lll	h	rrlr	s	lrrl	2	rlll 8
ll	b	llr	l	rlrr	t	lrlr	3	llll 9

Without Gaussian noise,
no Information and Communication Theory

A Morse code is a constrained sequence



A = 1 0 1 1 1
B = 1 1 1 0 1 0 1 0 1
C = 1 1 1 0 1 0 1 1 1 0 1

Etc.

Only strings of length 3 and 1 are allowed

Between letters we have 0 0 0 (3)
Between words we have 0 0 0 0 0 0 0 (7)

A language is also a constrained sequence (Zwynge)

Words:

sh?

qu always followed by -a or e or i or o

Order of words:

grammar

An example close to Immink's modulation code: the binary puzzle

0	1	0	1	1	0	1	0
0	1	1	0	0	1	0	1
1	0	0	1	0	1	0	1
1	0	1	0	1	0	1	0
0	1	0	0	1	1	0	1
1	1	0	1	0	0	1	0
0	0	1	1	0	1	1	0
1	0	1	0	1	0	0	1

RULES: Not more than two 0's and two 1's next to each other

Kees can do the last column

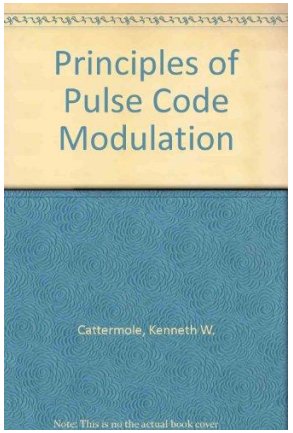
Remark: there is a solution!

Remark: The puzzle **can be solved**! But, the puzzle **has to be designed**!

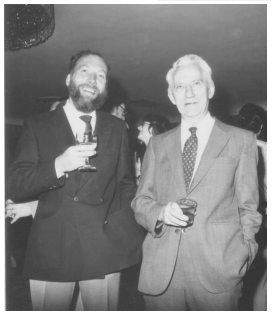
To do this, we need „binary mathematics"

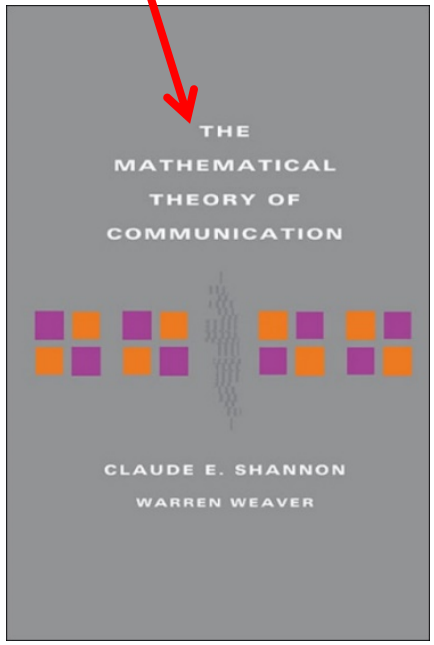
the calculations for the constrained sequences

Ken Cattermole

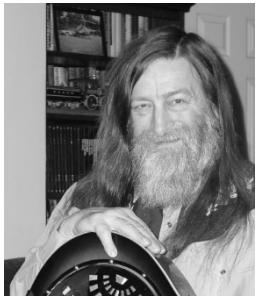


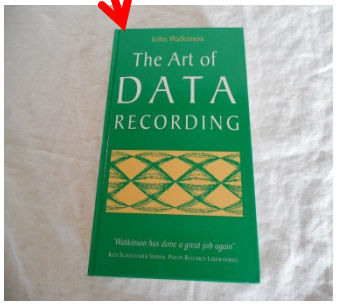
AES Convention, New York, 1985
Claude Shannon, and Kees Immink





John Watkinson



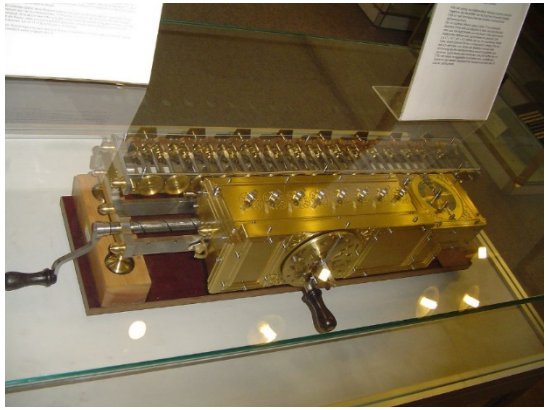


Who is the inventor of the binary mathematics?

Leibniz (1646-1716)

Explanation of Binary Mathematics, 1703

Explication de l'Arithmetique Binaire, 1703



He designed a binary computer,
Machina Arithmetica Dyadicae“

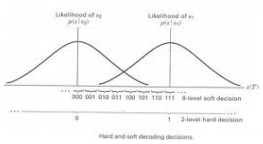
- Mechanical version in 1936 by Konrad Zuse
- Technical Museum München

Scientific (PhD) Genealogy of Kees Schouhamer Immink (coincidence?)

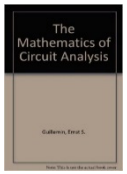
http://genealogy.math.ndsu.nodak.edu/

Friedrich Leibniz (1622, Leipzig, binary computing)

Carl Friedrich Gauß (1799, Göttingen, optics)

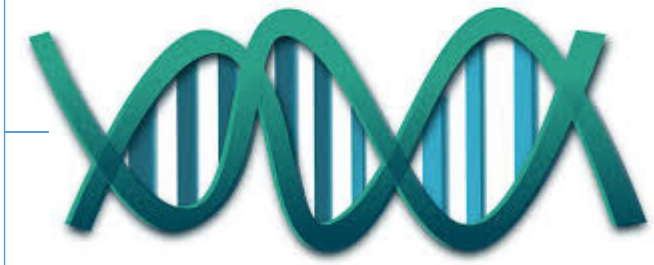


Ernst Guillemin (1926 München, circuits)



Fano

T.Kailath (Stanford, Control)



Kees Schouhamer Immink (1985, TU Eindhoven)